Trends and Developments in the Intensity of Steel Use
An Econometric Analysis

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ABSTRACT

The purpose of this thesis was to examine the shape of the intensity of steel use and to test if it exhibits an inverted U-shaped form as the intensity of use hypothesis suggests. This hypothesis states that the intensity of metal use in a country is related to its economic development. This thesis also investigates if high, middle and low income countries affect the intensity of steel use differently. The theoretical framework used in this thesis is the intensity of use hypothesis. Two variations of the intensity of steel use model were tested empirically through Ordinary Least Squares regressions. They were tested on data from 61 countries under the period 1970 to 2004. The results showed that the estimations correspond to the hypothesis when tested on all countries simultaneously, and on high income countries. This implies that the industrialised high income countries are those who have led the development and followed the shape of the intensity of use curve during this period of time, but the developing countries are believed to follow.
SAMMANFATTNING

ABSTRACT ...........................................................................................................................................I
SAMMANFATTNING .......................................................................................................................... II
TABLE OF CONTENTS ..................................................................................................................... III
LIST OF FIGURES AND TABLES ...................................................................................................... V
Chapter 1 - INTRODUCTION .............................................................................................................1
  1.1 Background .................................................................................................................................. 1
  1.2 Purpose ...................................................................................................................................... 2
  1.3 Methodology ............................................................................................................................. 2
  1.4 Scope and Limitations ................................................................................................................. 2
  1.5 Outline ..................................................................................................................................... 3
Chapter 2 - BACKGROUND ..............................................................................................................4
  2.1 Metal Demand History ............................................................................................................. 4
  2.2 Steel ......................................................................................................................................... 5
  2.3 Recent Developments in the Steel Market ................................................................................ 6
    2.3.1 Steel Consumption ............................................................................................................. 7
    2.3.2 Steel Production and Inputs .............................................................................................. 9
    2.3.3 Steel Trade ....................................................................................................................... 9
    2.3.4 Steel Prices and Capacity ................................................................................................. 10
Chapter 3 - THEORY ..........................................................................................................................11
  3.1 Metal Demand ........................................................................................................................... 11
  3.2 Intensity of Use Hypothesis ....................................................................................................... 11
  3.3 Earlier Studies ........................................................................................................................... 14
  3.4 Models of Steel Consumption .................................................................................................. 15
LIST OF FIGURES AND TABLES

Figure 2.1 World total apparent steel consumption, 1970-2004........................................7
Figure 2.2 Apparent steel consumption in China, 1970-2004........................................8
Figure 2.3 Apparent steel consumption in the world and the world except
    China, 1970-2004.............................................................8
Figure 3.1 Intensity of steel use and per capita income in South Korea, 1970-2004........12
Figure 3.2 True and estimated intensity of use curves.........................................................14

Table 4.1 Regressions results for all countries.................................................................18
Table 4.2 Regressions results for high income countries....................................................20
Table 4.3 Regressions results for middle income countries...............................................21
Table 4.4 Regressions results for low income countries....................................................22
Table 4.5 Summary of regression results.................................................................23
Chapter 1
INTRODUCTION

1.1 Background
Following the Great Depression and World War II the worldwide consumption of metals increased rapidly. This increase in consumption led to a concern about the supply of metal and a fear of early depletion. However, in the beginning of the 1970s the rate of consumption of metal began to decline. The metal market is known to be responsive to booms and recessions in the general economy, and as the world economic growth declined at the time, the decline in the rate of metal consumption was at first believed to be temporary. But the fall in growth rate of the metal industry turned out to be persistent (Radetzki and Tilton 1990).

One possible explanation for this reversed trend is the intensity of use hypothesis. This hypothesis states that the intensity of metal use depends on the economic development, that is, GDP per capita. The general shape of the function is an inverted U-formed curve. The reason for this is believed to be that the quantity of metal required changes over the development cycle of an economy. The undeveloped economy is mainly based on agriculture which is unmechanized, as the economic growth continues, and the manufacture, construction and the GDP per capita increases, the consumption of metal increases. When the economy develops, metal consumption declines, as the service sector grows. This sector is said to demand less material, therefore, the intensity of use of metal first slows down and then starts to decline when GDP per capita increases. The intensity of use curve has thus an inverted U-shaped form. The level of GDP per capita where the intensity of use starts to decrease is called the peak (Radetzki and Tilton 1990).

The intensity of use hypothesis has been tested on several metals, for example aluminium, copper, lead, steel, zinc and nickel. However, most of the studies examine the metal consumption in only one country under rather short periods of time. This thesis will examine data and the intensity of use hypothesis for several countries and under a longer period of time. Do intensity of use and the peak of the intensity of use differ between different countries?
Steel is regarded to be one of the most important and useful metals. The industrial revolution in China and India has had a major impact on mineral raw material demand and has contributed to the rapid increase of the growth in metal consumption. The consumption of steel is no exception (Humphreys 2007). The major impact these countries have on the steel market makes it interesting to investigate if these countries are close to the peak of the intensity of use curve. How does the intensity of steel use look like and where does the intensity of steel use peak? Is there any difference between high income countries and countries with lower income?

1.2 Purpose
The purpose of this thesis is to examine the pattern of intensity of steel use. The thesis will investigate the shape of the relationship between the intensity of steel use and the economic development, and empirically test if it exhibits the inverted U-shape. It will also examine if there is a difference between high, middle and low income countries. The analysis is based on steel consumption data from 61 countries, which includes countries with high, middle and low income, under the period 1970 to 2004.

1.3 Methodology
The theoretical framework used in this thesis is the intensity of use hypothesis which relates the intensity of material use to economic development. The thesis uses an econometric approach to analyse the steel consumption. Ordinary Least Squares regressions will be made on two different intensity of steel use models which differ in terms of number and types of independent variables. Statistical data on steel consumption as well as GDP and population data from 61 countries and 35 years will be collected and used as a panel data set.

1.4 Scope and Limitations
This thesis will only consider the apparent consumption of steel. The data available sets the limits of the thesis. The data set extends in time from 1970 to 2004 and the number of countries examined is limited to 61. This thesis will only consider the intensity of use hypothesis to examine the pattern of intensity of steel use.
1.5 Outline
The thesis is divided into six chapters. Chapter 1 consists of a general description of the problem, why this subject is relevant and interesting. It will also present the purpose, methodology used and the scopes and limitations. Chapter 2 describes the relevant background and includes metal demand history, what steel is and the developments on the steel market. Chapter 3 presents the theory that underlies the thesis. Earlier studies and reliability and validity are also presented in this chapter. In chapter 4 the empirical results are presented and analysed. In chapter 5 the final conclusions are discussed.
Chapter 2
BACKGROUND

2.1 Metal Demand History
In the years that followed after the Great Depression and World War II the industrial development made the consumption of metals increase rapidly, and so did the consumption and production of steel. The countries who led the growth in the steel market were Western Europe, North America, Japan and former Soviet Union (Labson, 1997). During this period many countries were destroyed by the war, especially in Eastern Europe, and the industrial development was low in developing countries. The increase in metal consumption led to concerns about the supply of metal and a fear of early depletion. However, in the beginning of the 1970s the growth rate in consumption of metal began to decline. The metal market is known to be responsive to booms and recessions in the general economy (Tilton, 1990). The two oil shocks that occurred during the 1970s affected the overall economy, and hence the consumption of metals. The per capita consumption declined significantly after 1973 and again after 1979, though not as significantly as after the first one. The metal prices were also affected by the two oil shocks and the prices rose considerably both around 1973 and 1979. This rapid increase in prices is most likely one of the reasons why metal consumption decreased (Tcha and Takasina, 2002). As the world economic growth declined during this period, the decline in metal consumption was at first believed to be temporary. But the fall in growth rate of the metal industry turned out to be persistent (Tilton, 1990).

In the 1980s and 1990s many believed that most metal industries, among those the steel industry, had expanded as much as it could and would not continue to grow (Humphreys, 2007). The increase in oil prices and macroeconomic policy implementations are reasons for the decline in growth of metal consumption traced to the 1970s. The first decline in 1973 was mainly caused by decline in economic growth and that the intensity of metal use fell in the developed countries. The second decline was caused by a new decline in economic growth and further falls in intensity of metal use in the developed countries together with a decline in economic growth also in the developing countries, partly because of the international debt crisis (Tilton, 1990).
As discussed above, the metal demand appears to be sensitive to variations in oil prices, and thus, the energy prices. The energy price can affect the metal demand in three ways. Firstly, through macroeconomic effects, secondly, as costs of synthetic substitutes increase when the energy costs go up. Thirdly, as energy is both material and capital compliments, this has effect both within a given production technology and the development of new technology because of higher energy prices. It has been shown that the first and third effects had the greatest impact on metal demand after the two oil shocks in the 1970s (Choe, 1991).

2.2 Steel

Steel is an alloy of iron and carbon. It contains mostly iron, no more than about one per cent is carbon and about two per cents are manganese and it also contains small amounts of silicon, phosphorus, sulphur and oxygen. There is not only one type of steel, and different types have different physical, chemical and environmental properties. Today it exist 3,500 different grades of steel. Steel is one of the most important materials in engineering and construction. Many of the objects that surround us contain steel; it is used in constructions and motor vehicle manufacturing as well as in dishwashers and surgery scalpels (IISI, n.d.).

Steel can be produced in two different ways. The first method makes steel out of raw material and scrap, and is called the integrated method. The second method is called electric arc furnace, EAF, which uses mainly scrap. The EAF method is easier to use as only scrap steel is needed. In 2005, 65.4 per cent of the steel produced was made using the integrated method, 31.7 per cent using the EAF method, 2.9 per cent of the steel was made using other methods. Steel is very easy to recycle, it is the most recycled material in the world today. Because of its magnetic property it is easy to separate from the waste stream and it can be recycled without loss of any of its properties, which also means that it can be recycled an endless number of times (IISI, n.d.).

The decrease in steel consumption growth has partly been caused by the improvements in efficiency throughout steel's whole lifecycle, from mining and processing to end use and recycling. There has been developments in the recovery of iron from iron ore as well as in energy saving. However, the biggest developments have been in the end use. It has, for example, been progress in the efficiency of steel use, developments of substitutes and
minimising of product size. As environmental issues and concerns about material waste came into focus the importance of recycling has increased (Choe, 1991).

Options available to producers to affect steel demand are limited. Firstly, steel’s standard quality attributes mean that steel is mainly viewed as a homogenous product. This means that the decrease in the demand of steel cannot, or at least not to any greater extent, be stimulated by product differentiation. This is also the reason why it is not possible to increase steel demand through increased advertising expenses. Furthermore, the specialised equipment required for steel production makes the steel industry structure non-competitive. Other barriers to enter are factors such as sunk costs, economies of scale and long-term contracts with inputs suppliers. As a result, the only competitive action possible, aside from price changes, is better quality, new products and faster delivery times, achieved through research and development (Abbott et al., 1999).

2.3 Recent Developments in the Steel Market
The steel market, as many other metal markets, has during the last decades undergone big regional changes, and these changes are still in progress. Steel consumption, production and trade patterns have changed dramatically and the new situation affects the whole world. Regions such as China, India and South Korea currently gains shares on the steel market, and now lead the growth. At the same time industrialised regions, previously dominant, such as the European Union, North America and Japan declines. However, they continue to be important operators on the steel market (Labson, 1997). This geographical shift in the steel market is caused partly by faster economic growth and partly by increased intensity of use in developing countries. It is believed that developing countries and especially the emerging developing countries will be the new engine of the growth in metal demand (Tilton, 1990).

The overall economic growth has been exceedingly high the last few years, the growth rates are the highest since the early 1970s. The most important factors that have influenced this unusually high economic growth are globalisation and the positive development in China and other developing economies. The steel market has been a part in this expansion (OECD, 2008).
2.3.1 Steel Consumption

The world steel consumption has increased every year since 1999, and has accelerated rapidly since 2002, as can be seen in figure 2.1 (OECD, 2004).

![Figure 2.1 World total apparent steel consumption, 1970-2004.](image)

Source: IISI (various years)

The growth in steel consumption rates in low and high income countries have moved in opposite directions (Choe, 1991). The rapid growth in China’s domestic steel consumption is the preliminary reason for the boost in steel demand (OECD, 2004). The industrial revolution in China requires huge amounts of raw materials, the size of the commodity boom created by China along with India, have no equivalence in world history. As steel is an important commodity used in construction it is one of those who have benefited the most from China’s industrialisation, about 70 per cent of the steel consumed in China is used for construction (Humphreys, 2007). Between 1995 and 2000 the annual growth of China’s steel consumption was 6.1 per cent on average, and between 2001 and 2004 the growth was 19.3 per cent (IISI, 2007). China’s rapid steel consumption growth during the last years can be seen in figure 2.2.
The world total steel consumption has increased by 6.5 per cent on average each year over the period 2001 to 2004, the increase during the same period not including China is 3.4 per cent. In 2004 China’s steel consumption made up 27.9 per cent of the world’s total steel consumption (IISI, 2007). This means that China’s contribution to steel consumption has led to an increase in the world consumption of steel. In figure 2.3 the steel consumption in the world except China is illustrated.

Along with China, India has increased its metal demand as well. The reason is an increase in per capita income together with an increase in the domestic consumption. There are, however, many differences between the two emerging economies. The intensity of metal use is
unusually high in China whereas the increased consumption of metals in India has followed the GDP growth (Humphreys, 2007).

### 2.3.2 Steel Production and Inputs

The production of steel has increased every year since 1998, and in 2004 world total production passed the one billion tonnes limit for the first time ever (IISI, 2007). As in the case of steel consumption it is mainly China that has contributed to the increase in production. The world steel production increased by an average of 3.6 per cent a year between 2000 and 2003. Under the same period China’s production increased by 20 per cent each year (OECD, 2004).

Although the prices of steel have increased for almost all steel products, the margins have decreased, as the prices of raw materials have increased as well due to the increased steel making capacity. The prices of both coke and steel scrap have increased rapidly. The coke price has increased with over 200 per cent between 2003 and 2004 and the scrap price has increased with 180 per cent in some countries between July 2003 and February 2004. The scrap prices are expected to remain high. Also the price of iron ore has increased but is expected to decline as China’s demand is expected to decline (OECD, 2004).

There is a difference between the countries that produces steel today and the countries in the previously dominant areas, North America and Eastern Europe. Those countries were domestic suppliers of iron ore, while many of the countries that currently grow as steel producers use imported iron ore. For example do many countries in Asia completely lack iron ore resources, among these are South Korea and Taiwan who are emerging steel producers. In addition, as international sea borne trade has developed the Western European producers have decreased their production of iron ore and these countries’ steel producers now needs to import as well. Consequently, the international iron ore market has expanded which creates opportunities for iron ore exporting countries such as Australia, Brazil and Sweden (Labson 1997).

### 2.3.3 Steel Trade

The increase in steel demand has led to an increase in the volume of steel trade. In 2003 the highest traded volume ever was achieved when it reached 247 million tonnes, the trade increased with 2.6 per cent compared to the year before. 29.0 per cent of the world steel
consumption was accounted by the world steel trade in 2003. China’s import of steel increased with 48.0 per cent between 2002 and 2003. Much of the world steel export was redirected to China (OECD, 2004).

2.3.4 Steel Prices and Capacity

Along with the positive development on the world steel market the steel prices have increased a great deal which makes the steel industry profitable. However, the increase in steel prices has lead to difficulties for the industries that consumes steel. China affects the whole steel market and especially the steel prices. The steel prices movements are closely correlated with the developments in China (OECD, 2004).

Previously, there has been a gap between capacity and the actual production in the steel market. During the last few years the gap has begun to decrease. In the OECD counties there has been a reduction in steel producing capacity. There has, however, been an increase in steel production in non-OECD countries such as Brazil, China, India and the Middle East. Not surprisingly, China is the country which has increased its capacity fastest (OECD, 2004).
Chapter 3
THEORY

3.1 Metal Demand
The demand of a good is derived through the price of the good, but also other factors such as the price of substitutes for the good, information and activity in the general economy can affect the demand. The major factors that determine the demand for a good is mathematically specified in the demand function. The demand function also describes the nature and relative influence of each factor, as well as the quantity of the good demanded. Given the demand function a demand curve can also be derived graphically. The demand curve illustrates the demand for the good at any given price level, assuming ceteris paribus. A supply curve can be derived in a similar way, and the intersection between the demand curve and supply curve determine the quantity demanded (Perloff, 2004). As most other goods metal applies to the rules of supply and demand. However, it should be noted that there is a difference between quantity demanded and quantity consumed. The quantity demanded consists of two components. There is the quantity demanded that is consumed and the quantity demanded to change inventories (Radetzki and Tilton, 1990).

3.2 Intensity of Use Hypothesis
To make long-term forecasts in metal demand the intensity of use (IU) hypothesis is a simple model that can be used. The intensity of use, $IU_t$ is defined as the ratio of metal consumption, $D_t$, to a county’s national income, $Y_t$, in year $t$ (Radetzki and Tilton, 1990):

$$IU_t = D_t/Y_t$$

(1)

In this model all the economic sectors are aggregated into a single measure, the entire economy. The real gross domestic product, GDP, measures the output of all goods and services in the economy (Roberts, 1996). The hypothesis states that the level of economic development in a country explains its intensity of metal use. A country’s economic
development is represented by its per capita income, that is, $GDP_t / Capita_t$. Thus, the intensity of metal use is a function of per capita income and is generally expressed:

$$IU_t = f(GDP_t / Capita_t)$$

(2)

Empirical measurements are needed to specify the exact nature of the relationship and there are usually variations among countries and materials. However, the relationship generally exhibits an inverted U-shaped curve, such as that shown in figure 3.1 (Radetzki and Tilton, 1990).

![Figure 3.1 Intensity of steel use and per capita income in South Korea, 1970-2004. Source: IISI (various years)](image)

The underlying assumption of the intensity of use hypothesis is that the consumption of metal in a country depends on how economically developed it is. When the income per capita is low, and the economic growth is in its early phases, the economy requires small volumes of material and thus metal, since it is mainly based on unmechanized agriculture. As the economic development continues, and the industrialisation begins, material intense activities such as construction and manufacturing will increase, and more and more material will be required. When the economy expands further, and the income per capita grows, the consumer demand will shift towards a service based economy. The service sector is presumed to require less material than the construction and manufacturing sectors. The economy is satiated with houses, factories, roads, cars, and less material will be required, as the income per capita
increases the shift will lead to a slowdown and eventually to decreasing intensity of metal use (Radetzki and Tilton, 1990).

The simplicity of the intensity of use hypothesis is its biggest advantage. The variables needed for estimating the intensity of metal use are relatively easy to obtain and it is also relatively easy to make realistic guesses about future GDP and population levels in various countries (Roberts, 1996). The income per capita works as an estimation of a country’s economic development and is readily available as GDP and population. With historical data on these and the metal consumption the relationship between intensity of use and the income per capita can be easily estimated (Radetzki and Tilton, 1990).

It is, however, not unlikely that the assumption underlying the intensity of use hypothesis, that there is a stable relationship between intensity of use and income per capita, is rather weak. The intensity of use is assumed to be connected to economic development through the shifts in the economy from agriculture to construction and manufacturing to services (Radetzki and Tilton, 1990). However, it is possible that other factors, such as new production technology, material substitutions, and long-run price trends, influence the intensity of use as well. These events do not seem to be linked to the per capita income, but rather with time (Guzmán et al., 2005). These events are usually separated and the occurrence is usually unevenly distributed in time. The speed of adoption and impact on metal use of new technology and material substitutions vary greatly due to a number of factors (Radetzki and Tilton, 1990).

Because of these events and other that are not linked to per capita income, the inverted U-shaped curve that the relationship between intensity of use and per capita income exhibits will shift over time. New technology and material substitutions can shift the curve both upwards and downwards. However, as new technology generally leads to a decrease in material requirement these factors will generally shift the curve downwards, as illustrated in figure 3.2. This means that an analysis of metal data will give an estimated intensity of use curve, illustrated by the heavy black curve in figure 3.2, which is a mixed combination of the true intensity if use curves and is not necessarily a good approximation for any of them. The estimated curve tends to underestimate the level of income per capita where the intensity of use is maximised and give a false estimation of the shape of the curve (Guzmán et al., 2005).
3.3 Earlier Studies

Tilton (1990) further developed the intensity of use hypothesis first formulated by Wilfred Malenbaum in 1975, which has been discussed earlier. Tilton et al. then applies this hypothesis to explain the world’s changes in metal consumption that began some time during the 1970’s. They also present a forecast of future metal consumption that draws from their findings.

The goal of the paper by Roberts (1996) is to find a model that can be used to explain past patterns of metal consumption and to forecast the consumption of metals over time, in relation to the economic activity. Roberts compare two different models, one that assumes that there are unlimited supply of data and another, the intensity of use hypothesis, which relays on the more realistic assumption that the available data is limited. The metal consumption models are applied on the consumption of aluminium, copper, lead and zinc. Roberts concludes that the first model explains the past trends in metal consumption in a good way. Even though the first model better explains the cyclical changes in metal consumption, the second simplified model generally follows the overall trends. The second model is easier to implement and requires less data. The intensity of use model can, thus, be used when the data available is restricted.

Guzmán et al. (2005) explores the trends in the Japanese intensity of copper use between 1960 and 2000. This study develops three different models of intensity of use and its purpose is to
find the causes behind the decline in Japan’s intensity of copper use. Firstly, a traditional model, secondly, a linear time model where a time trend is included, and thirdly, an exponential time model. These models are similar to the models used in this thesis. Guzmán et al. conclude that the third model best explains the intensity of copper use in Japan, which they find has increased due to income growth during the period. The intensity of copper use will continue to increase until a peak at a GDP level of $53,000, and thereafter decline. They also conclude that new copper saving technology has reduced the intensity of copper use during the period.

The results from these studies have been of great importance for the understanding of the variations in intensity of metal use. Though the intensity of steel use has been studied in separate countries, the intensity of use hypothesis has not yet been applied to a larger number of countries when it comes to the intensity of steel use. Nor has it been tested if the intensity of steel use is affects differently by high, middle and low income countries.

3.4 Models of Steel Consumption

Two models will be used to estimate the intensity of steel use curve, one model with a time trend and one model that includes a time dummy. The first model tries to avoid the weaknesses of a model that would not include some sort of time variable. As discussed earlier new production technology, material substitution and long-run price trends are not correlated with per capita income, but rather with time, see figure 3.2. This means that estimations from a model that disregards a time variable will be biased. Therefore, a time variable to function as a proxy for these factors is introduced in the time trend model. To account for the intensity of use curve’s inverted U-shape a quadratic relationship between the variables is assumed:

$$IU_t = \alpha_0 + \alpha_1 \left( \frac{GDP_t}{Capita_t} \right) + \alpha_2 \left( \frac{GDP_t}{Capita_t} \right)^2 + \alpha_3 t + \sum_{c=1}^{N-1} \alpha_{c+3} D_c$$

In equation (3) the $\alpha$s are parameters. Considering the shape of the curve $\alpha_1$ should be positive while $\alpha_2$ should be negative, as it first rises and then falls when per capita income increases. $\alpha_3$ is expected to be negative as new technology usually is material saving, as discussed earlier. $t$ is the time variable, it has the value one for 1970, two for 1971, and so forth until the value 35 for 2004. In this model it is assumed that the variables correlated with time changes
the intensity of use with a fixed quantity each year, for example by a given amount of kilos per US dollars of real GDP (Guzmán et al., 2005). \( C \) represents each country, where \( C=1 \) is Albania, \( C=2 \) Algeria and so forth until \( C=61 \) which is Venezuela. \( N \) is the total number of countries. \( D_C \) represents the dummy variables included in the model. A dummy variable is included for each country to make the regression estimates more efficient and to test if the effect of the qualitative factor is significant. The first dummy is denoted one for the first country and zero for all the other countries, the second dummy is denoted one for the second country and zero for all the other, and so forth. When the regressions are made all but one of the dummies is included (Dougherty, 2007).

The second model is specified in a way that makes it possible to avoid the influence of changes in steel prices caused by events such as the oil crises in the 1970s, another dummy is added to equation (3) instead of the time trend variable. This results in a new equation:

\[
IU_t = \alpha_0 + \alpha_1 \left( \frac{GDP_t}{\text{Capita}_t} \right) + \alpha_2 \left( \frac{GDP_t}{\text{Capita}_t} \right)^2 + \sum_{T=1}^{M-1} \alpha_{T+2} D_T + \sum_{C=1}^{N-1} \alpha_{C+3} D_C
\]

(4)

Also in equation (4) the \( \alpha \)s are parameters and \( D_C \) represent the dummy variables for the countries. \( T \) represents each year and \( M \) is the total number of years. \( D_T \) represents the time dummy variables. The first dummy has the value one for 1970 and zero for the rest of the years, the second dummy has the value one for 1971 and zero for the rest of the years, and so forth.

3.5 Reliability and Validity

In this thesis the method used to analyse the data is econometric estimations through Ordinary Least Squares regressions on intensity of use models for steel. The models are derived from the intensity of use hypothesis. The simplicity of the hypothesis is its biggest advantage, as discussed earlier. However, it exist some criticism of the hypothesis that regards the focus on per capita income. Firstly, events not correlated with income such as new technology and price trends can change the material composition of products. Secondly, alterations in consumers’ preferences can change the product composition of income. Furthermore, the product composition of income can also change when the economy develops and changes in
imports and exports and comparative advantage takes place. As discussed earlier these events may be correlated with time instead (Guzmán et al., 2005).

The empirical results are based on annual apparent steel consumption data measured in kilos from the International Iron and Steel Institute (various years), annual GDP data, measured in real (1990) US dollars from the United Nations (2008), and annual population data from the United Nations (2006). There are a total of 61 countries in the data set. These countries have been divided into different income groups according to the World Bank list of economies (2007). The groups are high income, upper middle income, lower middle income and low income countries. In this thesis the low and lower middle income groups will be added together and be referred to as low income countries, the upper middle income group will be referred to as the middle income countries. A list of all the countries and the three groups can be found in Appendix 1 and 2 respectively.

The statistics on GDP and population is believed to be reliable. However, some questions regarding the reliability of the steel data can be raised as the data is reported and, hence, derived from data on production, trade and inventory changes. In some cases the data published on steel production and trade by the countries are so incomplete that the figures are based on qualified guesses by specialists. The statistics on inventory changes are even more difficult to collect. In less developed countries and in countries earlier centrally planned nearly no data is reported. Also in developed countries statistics from traders and fabricators are limited, even though the statistics on stocks at larger producers and metal exchanges are available (Radetzki and Tilton, 1990).
In this chapter the results from the regressions are presented. The method used for both the time trend model, equation (3) and the time dummy model, equation (4) was Ordinary Least Squares regressions. The regressions were first made on the data for all 61 countries, secondly, on the high income countries, thirdly, on the middle income countries and, finally, on the low income countries. The results are presented in this order and summarised by a comparison in the end of the chapter.

4.1 All Countries

Equations (3) and (4) were used to estimate the intensity of steel use for all countries in the data set under the period 1970 to 2004. Table 4.1 shows the results from the regressions on all countries.

<table>
<thead>
<tr>
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<th>Time trend model</th>
<th></th>
<th>Time dummy model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-value</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Constant</td>
<td>0.058</td>
<td>13.322***</td>
<td>0.044</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>-0.792*10^{-6}</td>
<td>-1.631</td>
<td>0.155*10^{-5}</td>
</tr>
<tr>
<td>(GDP per capita)^2</td>
<td>0.153*10^{-10}</td>
<td>1.257</td>
<td>-0.285*10^{-10}</td>
</tr>
<tr>
<td>Time trend</td>
<td>-0.001</td>
<td>-11.128***</td>
<td>-</td>
</tr>
<tr>
<td>Adjusted R^2</td>
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<td></td>
<td>0.7793</td>
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<tr>
<td>F-value</td>
<td>110.72</td>
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<td>74.52</td>
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<td>Optimum^1</td>
<td>25,866 (min)</td>
<td></td>
<td>27,122 (max)</td>
</tr>
</tbody>
</table>

´statistically significant at a 10 per cent level
´´statistically significant at a 5 per cent level
´´´statistically significant at a 1 per cent level

^1 To find the optimum level of a function it has to be differentiated and then set equal to zero and solved. Whether the optimum point is a maximum or a minimum depends on the sign of the second order derivative. If it is positive it is a minimum point, and if it is negative it is a maximum point (Jacques, 2006).
The regression results with the time trend model shows that the coefficient for GDP per capita is negative and the coefficient for the squared GDP per capita is positive. As mentioned earlier, the coefficient for GDP per capita should be positive and the coefficient for the squared GDP per capita should be negative for the relationship between intensity of use and GDP per capita to exhibit the inverse U-shape, and hence, follow the intensity of use hypothesis. This means that the estimations of this model on the data from all countries instead suggest that the form of the relationship is U-shaped. However, neither of the coefficients are statistically significant and nothing can be said about them for certain. The optimum level of per capita income is in this case a minimum at 25,866 US dollars. These results suggest that the intensity decreases with an increasing per capita income until a minimum at 25,866 US dollars and then begins to increase with increasing per capita income. The time trend coefficient is negative as expected. Thus, the intensity of use curves shifts downwards over time. This is probably caused by developments in production technology towards more steel-saving production and the emergence of new steel substitutes. Then less steel is demanded for producing the same products. Still, this model does not provide a good explanation of the intensity of steel use. A reason for this can be that other events than new technology and substitutes are associated with time but are of a more temporary character. One example of such an event is the oil shocks in the 1970s and its aftermath.

In the time dummy model a time dummy is introduced. This dummy tries to correct the model for events like the oil crises in the 1970s that influence the steel demand and hence the intensity of steel use. The estimated coefficient for GDP per capita and squared GDP per capita in this model has a positive and negative sign respectively, and the relationship exhibits an inverse U-shape. The optimum is in this case a maximum at 27,122 US dollars, which means that the intensity of steel use first increases with increasing per capita income and after a peak at 27,122 US dollars decreases with increasing income per capita. The level at which the per capita income peaks is quite plausible. Ten out of the 61 countries had achieved this per capita income level in 2004. It is interesting to note that China’s per capita income in 2004 was just over 1,200 US dollars, which means that they are far from the current peak level of per capita income. The time dummy model does also provide the best fit according to the adjusted R². The time dummy model is therefore the model that best describes the relationship between intensity of steel use and per capita income for all the countries. It does also exhibit the inverse U-shaped form described in the intensity of use hypothesis. This
means that the events of a temporary character have influenced the intensity of steel use under this period of time.

### 4.2 High Income Countries

Equations (3) and (4) were used to estimate the intensity of steel use for the high income countries under the period 1970 to 2004. Table 4.2 shows the results from the regressions on high income countries.

<table>
<thead>
<tr>
<th></th>
<th>Time trend model</th>
<th>Time dummy model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-value</td>
</tr>
<tr>
<td>Constant</td>
<td>0.033</td>
<td>9.418***</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>0.197*10^-7</td>
<td>0.069</td>
</tr>
<tr>
<td>(GDP per capita)^2</td>
<td>-0.180*10^-10</td>
<td>-3.043***</td>
</tr>
<tr>
<td>Time trend</td>
<td>-0.708*10^-4</td>
<td>-1.546</td>
</tr>
<tr>
<td>Adjusted R^2</td>
<td>0.7924</td>
<td></td>
</tr>
<tr>
<td>F-value</td>
<td>125.53</td>
<td></td>
</tr>
<tr>
<td>Optimum</td>
<td>549.28 (max)</td>
<td></td>
</tr>
</tbody>
</table>

The results from the estimations of the time trend model shows that the GDP per capita and the squared GDP per capita has a positive and a negative sign respectively. This means that they do support an inverse U-shaped form. The estimated coefficient for GDP per capita is, however, not statistically significant and nothing can be said about it for certain. The optimum is a maximum at 549.28 US dollars. The results suggest that the intensity of steel use increases with an increasing per capita income until the peak at 549.28 US dollars, and then begins to decrease with increasing per capita income. The point of the peak of the intensity of steel use is a rather low level of per capita income. All high income countries and all except three countries (Bangladesh, Kenya and Tanzania) in the whole data set, have exceeded that income per capita level some time between 1970 and 2004. The estimation of the time coefficient for the high income countries shows that the time trend coefficient possesses a negative sign as expected. Thus, the development of new technology and substitutes leads to a lower demand for steel. The coefficient is, however, not statistically significant which means that the estimated value of the coefficient is not correct for certain.

The estimated coefficients for the time dummy model do have the correct signs as well, for the relationship to follow the intensity of use hypothesis. The estimated coefficient for GDP per capita is, however, not statistically significant and nothing can be said about it for certain.
The optimum is a maximum at 2024 US dollars. Thus, the intensity of steel use first increases with increasing per capita income and after a peak at 2024 US dollars decreases with increasing income per capita. Even though the peak of the intensity of use curve comes at a higher level of per capita income it is still rather low. The time dummy model does explain the relationship best of the two models for the high income countries as it does provide a slightly better fit than the time variable model according to the adjusted $R^2$.

4.3 Middle Income Countries

Equations (3) and (4) were also used to estimate the intensity of steel use for middle income countries under the period 1970 to 2004. Table 4.3 shows the results from the regressions on middle income countries.

<table>
<thead>
<tr>
<th></th>
<th>Time trend model</th>
<th></th>
<th>Time dummy model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-value</td>
<td>Coefficient</td>
<td>t-value</td>
</tr>
<tr>
<td>Constant</td>
<td>0.103</td>
<td>6.850''</td>
<td>0.050</td>
<td>2.228''</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>-0.291*10^{-5}</td>
<td>-0.456</td>
<td>-0.675*10^{-7}</td>
<td>-1.017</td>
</tr>
<tr>
<td>(GDP per capita)^2</td>
<td>-0.128*10^{-9}</td>
<td>-0.356</td>
<td>0.292*10^{-11}</td>
<td>0.008</td>
</tr>
<tr>
<td>Time trend</td>
<td>-0.002</td>
<td>-9.974'''</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Adjusted R^2</td>
<td>0.7274</td>
<td></td>
<td>0.7169</td>
<td></td>
</tr>
<tr>
<td>F-value</td>
<td>81.78</td>
<td></td>
<td>24.95</td>
<td></td>
</tr>
<tr>
<td>Optimum</td>
<td>-1.14 (max)</td>
<td></td>
<td>21,812 (min)</td>
<td></td>
</tr>
</tbody>
</table>

For the middle income countries the estimation of the coefficients using the time trend model shows that the GDP per capita and the squared GDP per capita both have negative signs. However, neither of them is statistically significant. The relationship does not exhibit an inverse U-shape, instead the intensity of steel use falls with increasing speed. The optimum is a maximum at minus 1.14 US dollars, which is not possible. The time trend coefficient possesses a negative sign, as expected, and it is statistically significant. The fit of the model is slightly better than for the time dummy model according to the adjusted $R^2$. The intensity of use hypothesis clearly fails to explain the pattern of the intensity of steel use for middle income countries with the time trend model. The reason for this might be that these countries not yet have reached the peak of the intensity of use curve.

The estimated coefficient for GDP per capita is negative and the coefficient for the squared GDP per capita is positive in the time dummy model. Neither of them are statistically significant. The relationship does not exhibit the inverse U-shaped form. The optimum level is
a minimum at 21,812 US dollars. It suggests that the intensity of steel use decreases with an increasing per capita income until a minimum of 21,812 US dollars and then begins to increase with increasing per capita income. That is, it exhibits a U-shaped form instead. Also this model fails to explain the past intensity of steel use with the intensity of use hypothesis.

4.4 Low Income Countries

Equations (3) and (4) were used to estimate the intensity of steel use for low income countries under the period 1970 to 2004. Table 4.4 shows the results from the regressions on low income countries.

Table 4.4 Regressions Results for Low Income Countries

<table>
<thead>
<tr>
<th></th>
<th>Time trend model</th>
<th></th>
<th>Time dummy model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>t-value</td>
<td>Coefficient</td>
<td>t-value</td>
</tr>
<tr>
<td>Constant</td>
<td>0.063</td>
<td>7.803***</td>
<td>0.068</td>
<td>6.252***</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>-0.244*10^{-4}</td>
<td>-2.650***</td>
<td>-0.278*10^{-4}</td>
<td>-3.048***</td>
</tr>
<tr>
<td>(GDP per capita)^2</td>
<td>0.935*10^{-8}</td>
<td>3.703***</td>
<td>0.918*10^{-8}</td>
<td>3.672***</td>
</tr>
<tr>
<td>Time trend</td>
<td>-0.281*10^{-3}</td>
<td>-2.888***</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Adjusted R^2</td>
<td>0.8271</td>
<td>-</td>
<td>0.8280</td>
<td>-</td>
</tr>
<tr>
<td>F-value</td>
<td>144.60</td>
<td>61.12</td>
<td>144.60</td>
<td>61.12</td>
</tr>
<tr>
<td>Optimum</td>
<td>1,303 (min)</td>
<td>1,513 (min)</td>
<td>1,303 (min)</td>
<td>1,513 (min)</td>
</tr>
</tbody>
</table>

The regression results with the time trend model shows that the GDP per capita posses a negative sign and the squared GDP per capita posses a positive sign. The optimum income level is a minimum at 1,303 US dollars. Thus, the estimation of the model suggests that the intensity of steel use falls with an increasing per capita income until a minimum of 1,303 US dollars, and then begins to increase with increasing per capita income. The estimation of the time coefficient for the low income countries shows that the time trend coefficient possesses a negative sign as expected. Even though all the estimated coefficients are statistically significant at a one per cent significance level, the intensity of use hypothesis does not explain the intensity of steel use for this group of countries either. As these are low income countries it is even more likely that they have not yet reached the peak on the intensity of use curve.

The estimated coefficients for the time dummy model do not have the correct signs either for the intensity of use hypothesis as GDP per capita is negative and the squared GDP per capita is positive. It suggests that the intensity decreases with an increasing per capita income until a minimum of 1,513 US dollars and then begins to increase with increasing per capita income. Also all the estimated coefficients in this model are statistically significant and this model
provides a slightly better fit than the time trend model according to the $R^2$. As the time dummy model, the intensity of use hypothesis fails to explain the intensity of steel use between 1970 and 2004.

4.5 Comparison

When the time dummy model is used the intensity of steel use for all the countries can be explained with the intensity of use hypothesis. For the high income countries both the models estimated supports that the intensity of steel use in these countries can be explained with the intensity of use hypothesis. For the middle and low income countries the results show that neither of the models can be used to explain the intensity of steel use. These results are summarised in table 4.5.

<table>
<thead>
<tr>
<th>Table 4.5 Summary of Regression Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time trend model</strong></td>
</tr>
<tr>
<td>All countries</td>
</tr>
<tr>
<td>High income</td>
</tr>
<tr>
<td>Middle income</td>
</tr>
<tr>
<td>Low income</td>
</tr>
</tbody>
</table>

The reason why the models support the intensity of use hypothesis for all countries might be that a wide variety of countries are included, from very low income, developing countries to high income, industrialised countries. It is realistic to believe that countries in different stages of economic development and different levels of intensity of use are represented among the countries analysed in this thesis. The reason why the time trend model does not follow the intensity of use hypothesis for all countries, while it does for the high income countries may be the influence of the oil shocks in the 1970s. High income and low income countries were affected differently and this might have affected the result when all countries are included.

The results from the estimations of the high income countries imply that these have led the development. The high income countries appear to already have followed the inverse U-shaped pattern during this period. The failure of the models to explain the intensity of steel use for low and middle income countries has probably something to do with the fact that they not are developed enough. This means that they may not yet have started to decline in or reached the peak of the intensity of steel use. The reason why their intensity of steel use curves exhibits U-shaped forms instead of inverse U-shaped forms might be that they all are
within the same level of per capita income but varies in the intensity of steel use. It is, however, likely that these countries will follow the developed countries. The peak of the intensity of use curve is according to the results for all countries currently at an income per capita level of 27,122 US dollars.
The purpose of this thesis was to empirically test the intensity of steel use for 61 countries and 35 years to empirically investigate the shape of the relationship between the intensity of steel use and the economic development. The purpose was also to test if there is any difference in the intensity of steel use between high, middle and low income countries.

The analysis shows that the inverse U-shaped form of the intensity of use curve that the intensity of use hypothesis suggests is in fact true when results from all countries as well as for the high income countries are evaluated. The intensity of steel use in the middle and low income countries does, however, not exhibit the inverse U-shaped form and the intensity of use hypothesis fails to explain the intensity of steel use for these countries. The reason for this might be that the low economical development level in these countries means that the intensity of use curve not yet has reached its peak. According to the results the point where the intensity of use peaks is at a per capita income of 27,122 US dollar.

The results suggest that it is the high income countries that have led the intensity of steel use during the period between 1970 and 2004, and followed the intensity of use’s inverted U-shaped curve. During recent years developing countries such as China and India has, however, grown rapidly. The consumption of steel has increased dramatically, especially in China, and it is believed that these countries now will follow the already industrialised countries.

The hypothesis that variables correlated with time, such as new technology and material substitution, are important for the intensity of use curve to be estimated correctly, is supported by these results. Moreover, it was found that events associated with time but of a more temporary character, as the oil shocks in the 1970s, also is important to control for. In addition, it was shown that there is a difference in influence on intensity of steel use between high income and middle and low income countries. The high income countries have during the period had a positive effect on the intensity of steel use.
These findings imply that even though new technology and material substitution will reduce the demand for steel, the rapid growth and the massive increase in steel demand in developing countries will contribute to a continued growth on the steel market. Although these countries are growing fast they still probably are far from the peak of intensity of steel use. This has important implications for both steel exporting countries and steel producing companies.
REFERENCES


Appendix 1

All Countries

1. Albania
2. Algeria
3. Argentina
4. Australia
5. Austria
6. Bangladesh
7. Belgium-Luxemburg
8. Brazil
9. Bulgaria
10. Canada
11. Chile
12. China
13. Colombia
14. Cuba
15. Denmark
16. Egypt
17. Finland
18. France
19. Germany
20. Greece
21. Hong Kong
22. Hungary
23. India
24. Indonesia
25. Iran
26. Ireland
27. Israel
28. Italy
29. Japan
30. Kenya (1975-)
31. Kuwait
32. Lebanon
33. Libyan Arab Republic
34. Malaysia
35. Mexico
36. Morocco
37. Netherlands
38. New Zealand
39. Nigeria
40. Norway
41. Pakistan
42. Peru
43. Philippines
44. Poland
45. Portugal
46. Romania
47. Saudi Arabia
48. Singapore
49. South Africa
50. South Korea
51. Spain
52. Sweden
53. Switzerland
54. Syrian Arab Republic
55. Tanzania (1975-)
56. Thailand
57. Tunisia
58. Turkey
59. United Kingdom
60. United States
61. Venezuela
Appendix 2
Countries by World Bank Classification

<table>
<thead>
<tr>
<th>Low Income</th>
<th>Middle Income</th>
<th>High Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>Argentina</td>
<td>Australia</td>
</tr>
<tr>
<td>Algeria</td>
<td>Brazil</td>
<td>Austria</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Bulgaria</td>
<td>Belgium-Luxemburg</td>
</tr>
<tr>
<td>China</td>
<td>Chile</td>
<td>Canada</td>
</tr>
<tr>
<td>Colombia</td>
<td>Hungary</td>
<td>Denmark</td>
</tr>
<tr>
<td>Cuba</td>
<td>Lebanon</td>
<td>Finland</td>
</tr>
<tr>
<td>Egypt</td>
<td>Libyan Arab Republic</td>
<td>France</td>
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<td>India</td>
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<td>Germany</td>
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<td>Indonesia</td>
<td>Poland</td>
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<td></td>
<td></td>
<td>United States</td>
</tr>
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</table>

(World Bank, 2007)